Innovative Instrumentation and Analysis of the Temperature Measurement for High Temperature Gasification

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Presentation Organization

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Objectives

- To develop an innovative instrumentation and analysis for high temperature measurements in gasification using the specialized thermocouple along with two cleaning methods and other unique approach.
- To reduce a significant amount of the operation / maintenance costs and increase the gas production rate.

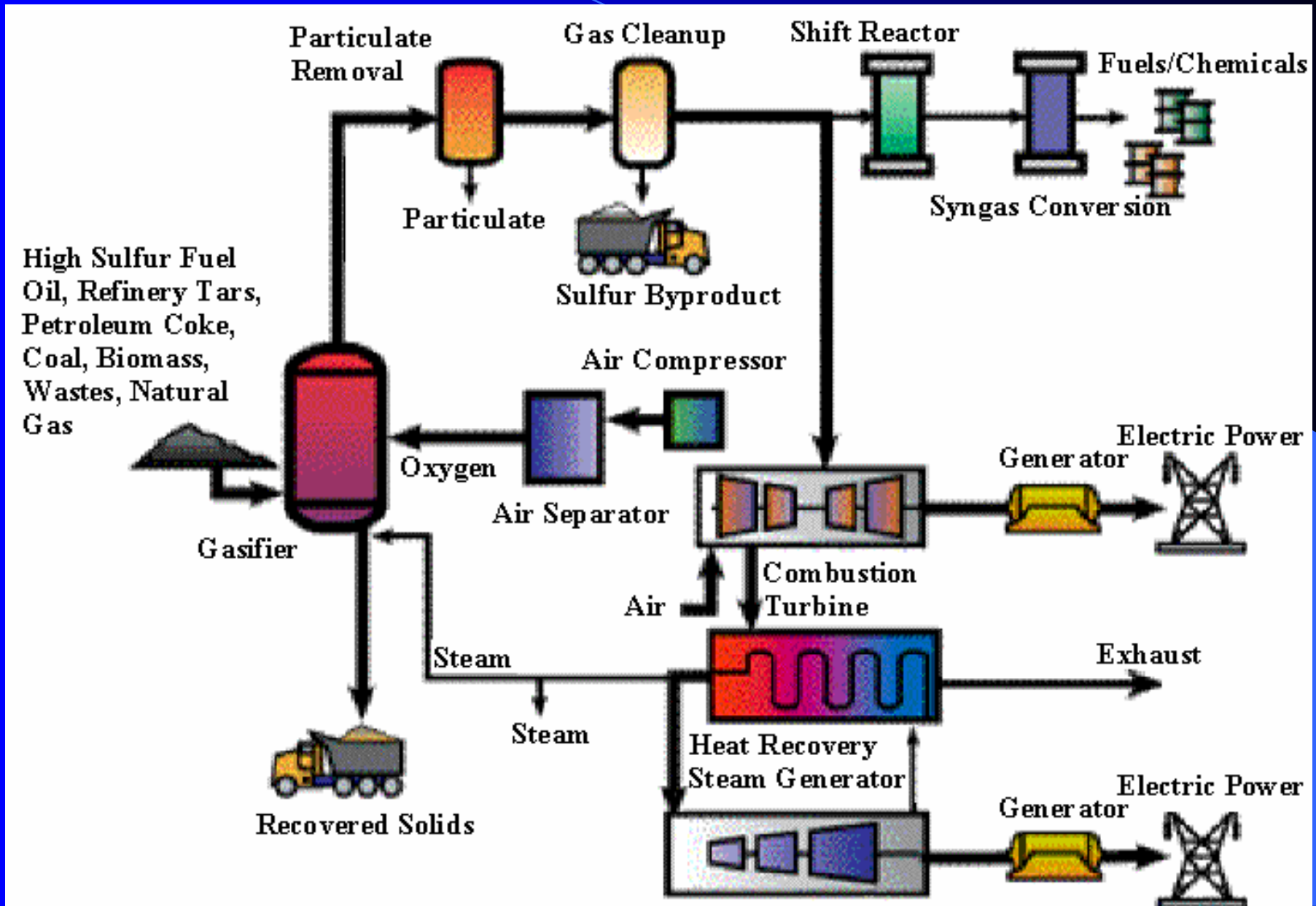
Introduction

- It is well known that gasification offers the cleanest, most efficient method available to produce synthesis gas from low or negative-value carbon-based feed stocks such as coal, petroleum coke, high sulfur fuel oil or materials that would otherwise be disposed as waste. The gas can be used in place of natural gas to generate electricity or as a basic raw material to produce chemicals and liquid fuels.

Introduction (cont.)

- Any feasible instrumentation for temperature measurement in gasifiers will be operated for a long time (at least 150 hours) in an environment, which contains granular carbonaceous material, sticky and/or molten ash and gas containing significant quantities of methane, water vapor, carbon monoxide and hydrogen. Also, low concentrations of alkali metals, hydrogen sulfide, hydrogen chloride and ammonia can be found in the environment.

Typical Gasifier System



Importance of Temperature Measurements in Gasification

- The gasifier must be operated at a temperature high enough for the ash in the slid fuel to melt.
- Temperature measurements are critical to load changes of gasification.
- Operation at too low temperature could cause the molten slag, which may leads to shutting-down of the gasifiers.

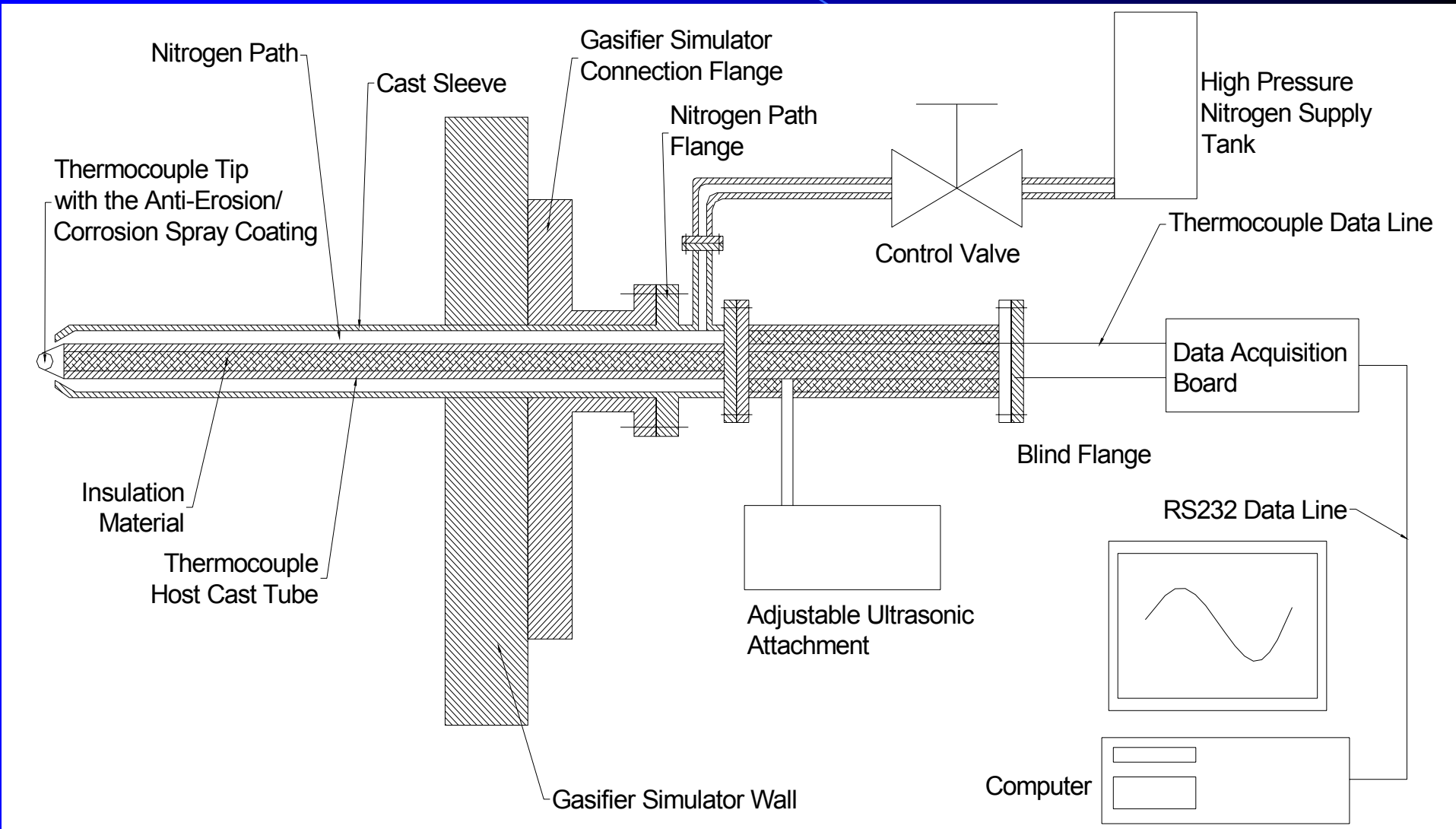
Temperature Measurements Techniques in Gasification

1. High Temperature Thermocouple
2. Acoustic Method
3. Remote Pyrometer
4. Thermal Expansion Thermometer
5. Fluorescence Thermometer
6. Optical Scattering Thermometer

Problems Associated with High Temperature Thermocouple in Gasification

- High temperature thermocouple has a limited life because of its susceptibility from corrosive environment in gasification process.
- Accuracy drops significantly after a long period of run.

The Instrumentation for Gasifier Temperature Measurements



The Instrumentation for Gasifier Temperature Measurements (cont.)

- The instrumentation for temperature measurements consists of a specially designed thermocouple with special HVOF thermal sprayed coating and two cleaning methods: high-pressure nitrogen injection cleaning, and ultrasonic dirt peeling, which make the instrumentation design unique.

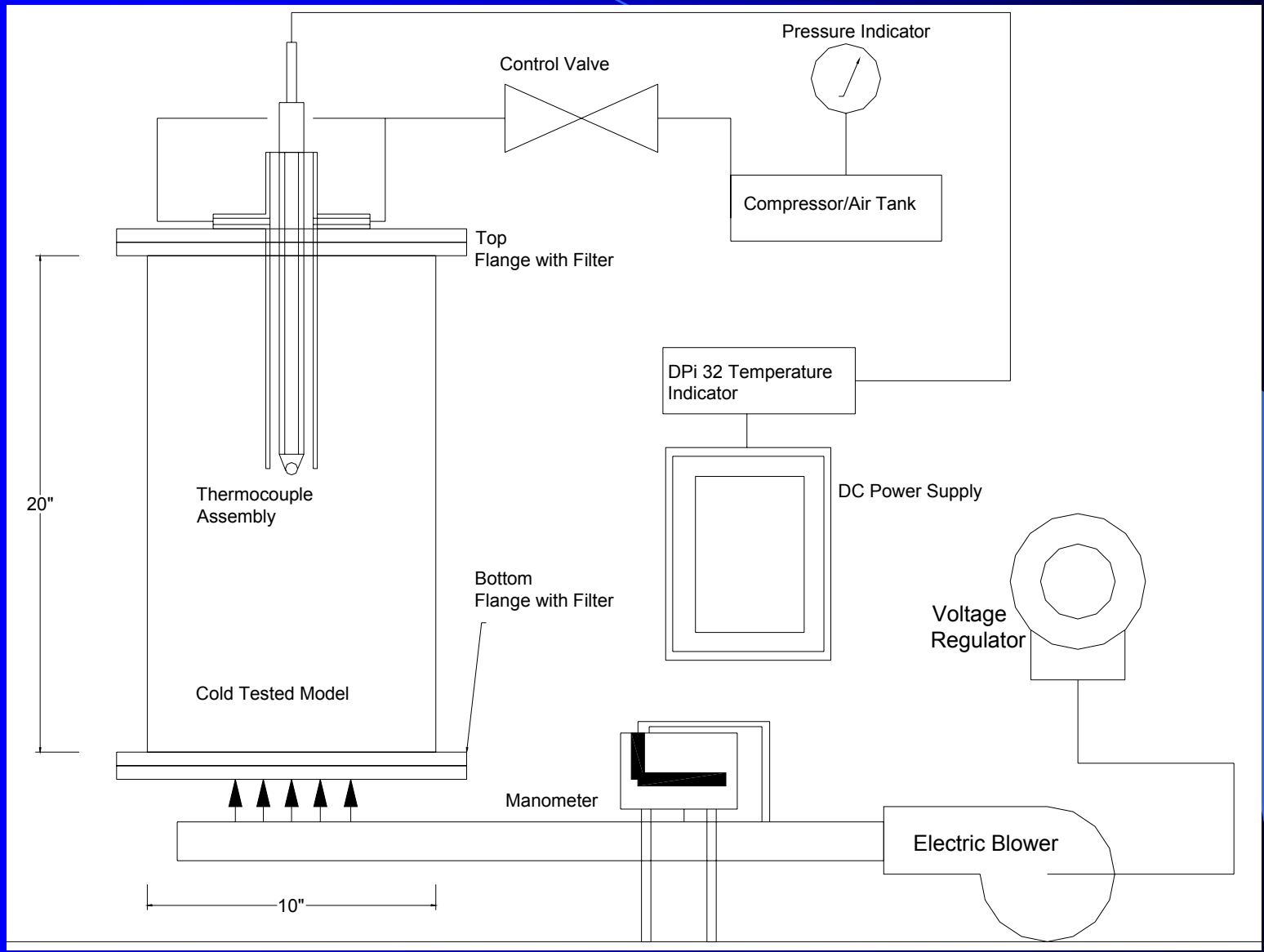
Thermocouple Cleaning Methods

1. For the high-pressure nitrogen injection cleaning, the high-pressure nitrogen stream will be directed to the thermocouple tip to blow off loose dirt from the thermocouple.
2. In the ultrasonic dirt peeling method, an ultrasonic attachment will be installed at the end of the thermocouple assembly. The vibration shall prevent the dirt from attaching to the thermocouple.

HVOF Thermal Sprayed Coating

1. At the thermocouple's tip and the thermocouple assembly, where the most corrosion and erosion occur, the high velocity oxygen flame (HVOF) NiAl-40Al2O3 inter-metallic-ceramic coating will be applied to protect the thermocouple tip from the harsh environment.

Gasifier Simulator Cold Model Design



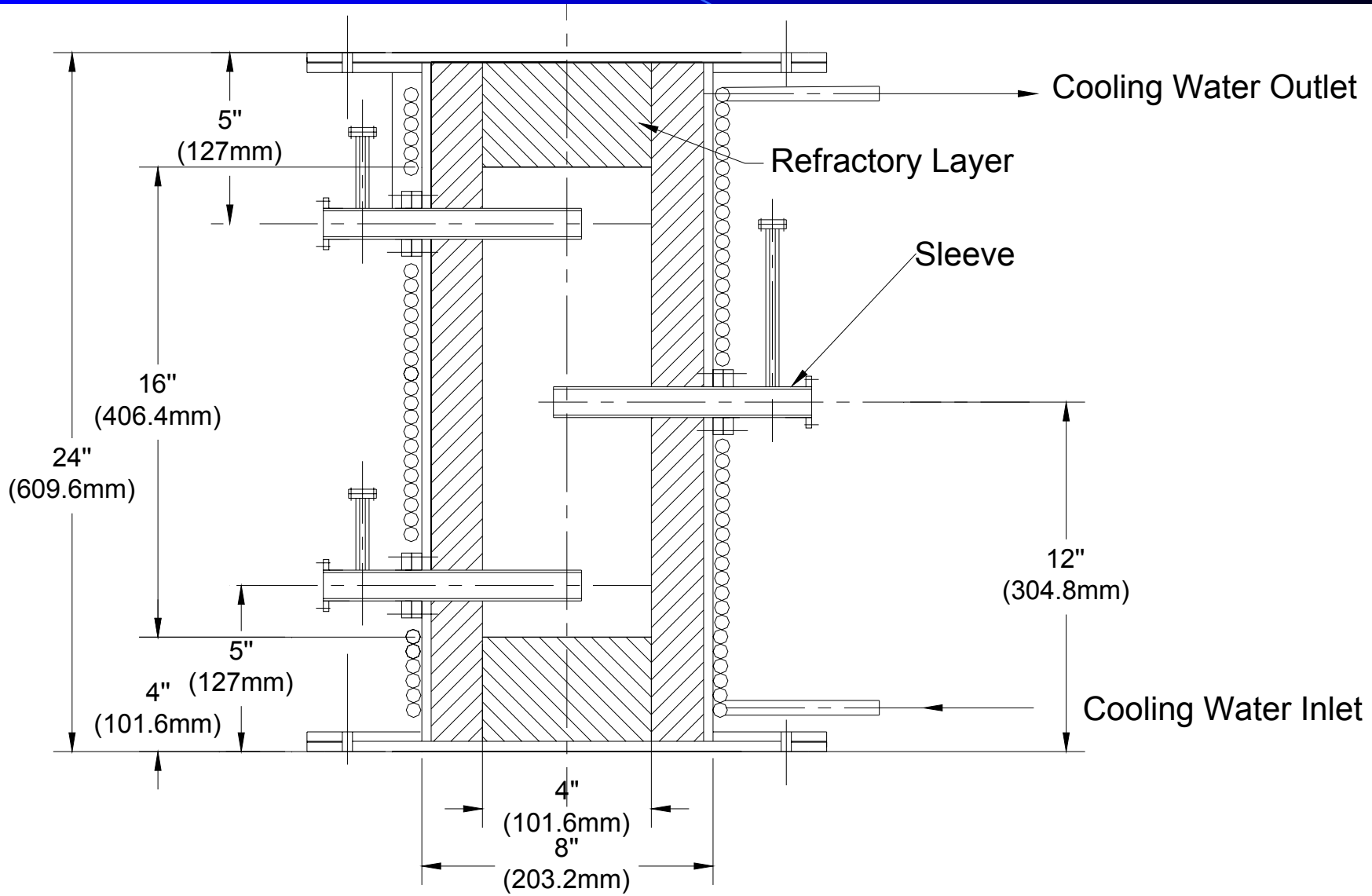
Cold Model Tests of the Proposed Instrumentation

- The filtered sawdust particle was used as the fluidizing particle because the particle selection test showed that the filtered sawdust particles had the best fluidizing performance and the best PIV laser sensitivity than glass bead and grinded organic particle.
- The filtered sawdust particles have a size range from 450 μm to 600 μm. Particle density and bulk density are1005 kg/m^3, and 419 kg/m^3 respectively.

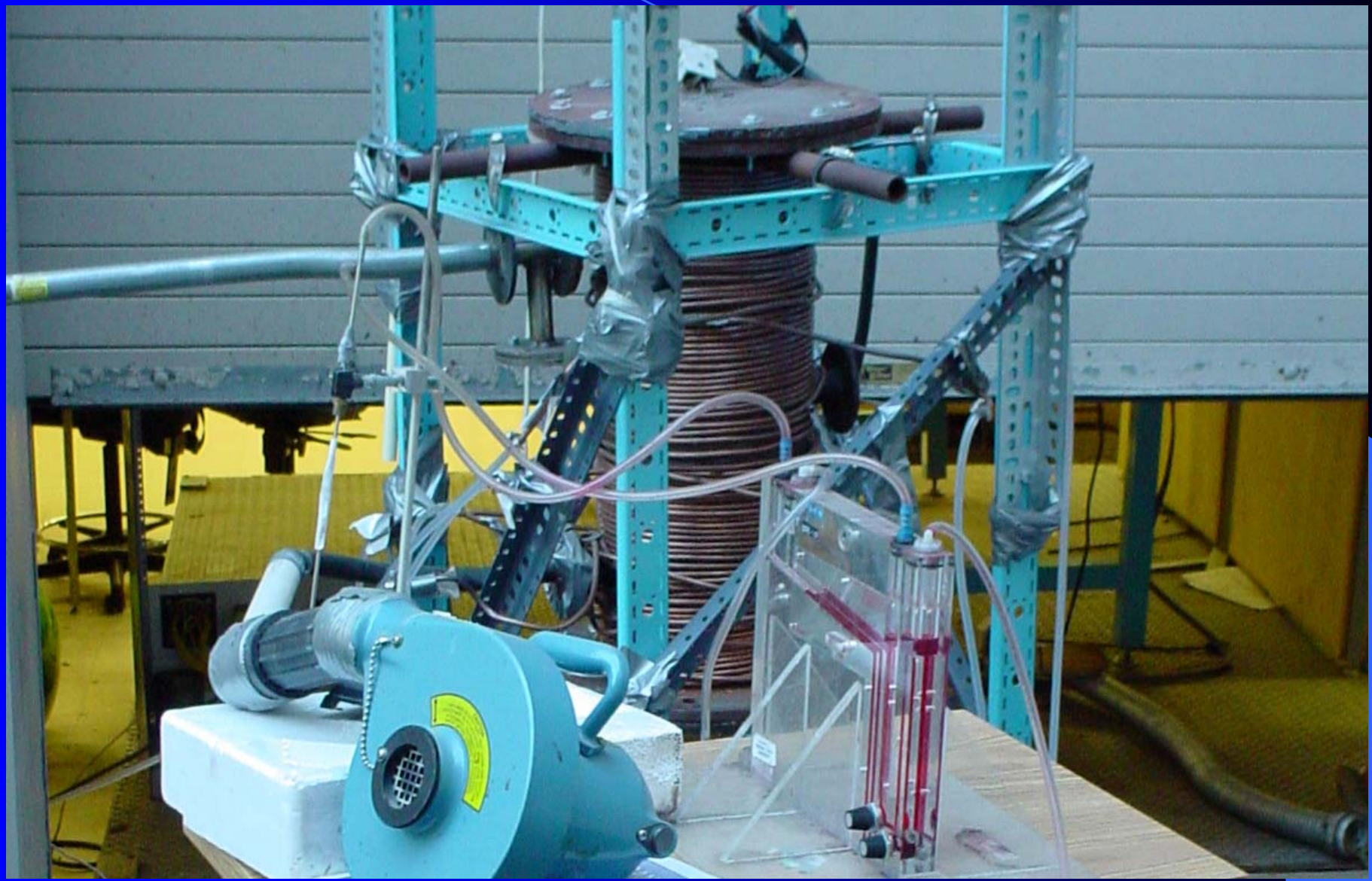
Cold Model Test Results and Discussion

- Proved the accumulation of the flying ash on the thermocouple.
- Showed that the high-pressure nitrogen injection does clean the thermocouple by blowing off the accumulated ash.
- Showed that low frequency vibration helps to prevent the ash from accumulating on the thermocouple.

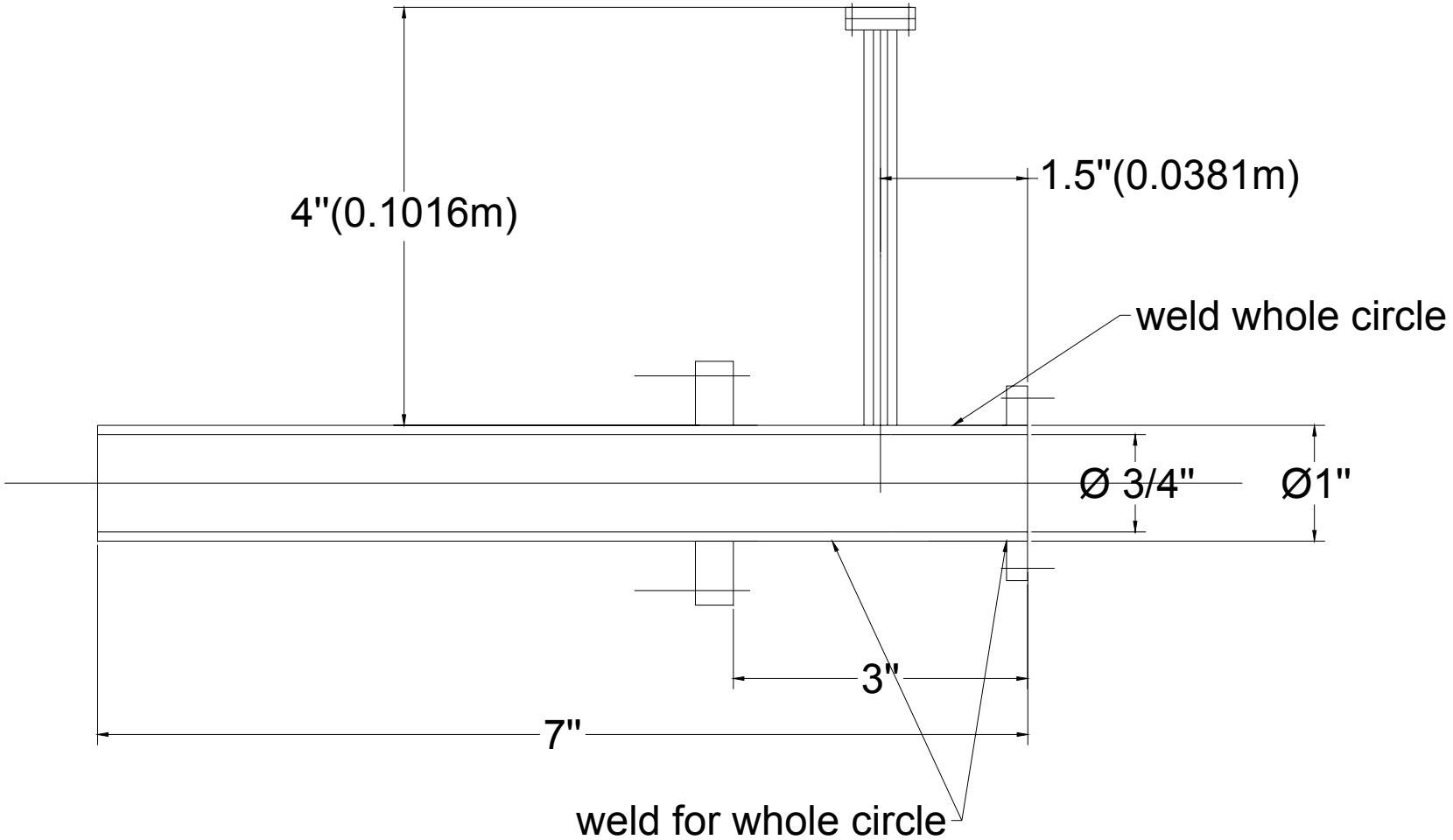
Gasifier Simulator Hot Model Design



Gasifier Simulator Hot Model



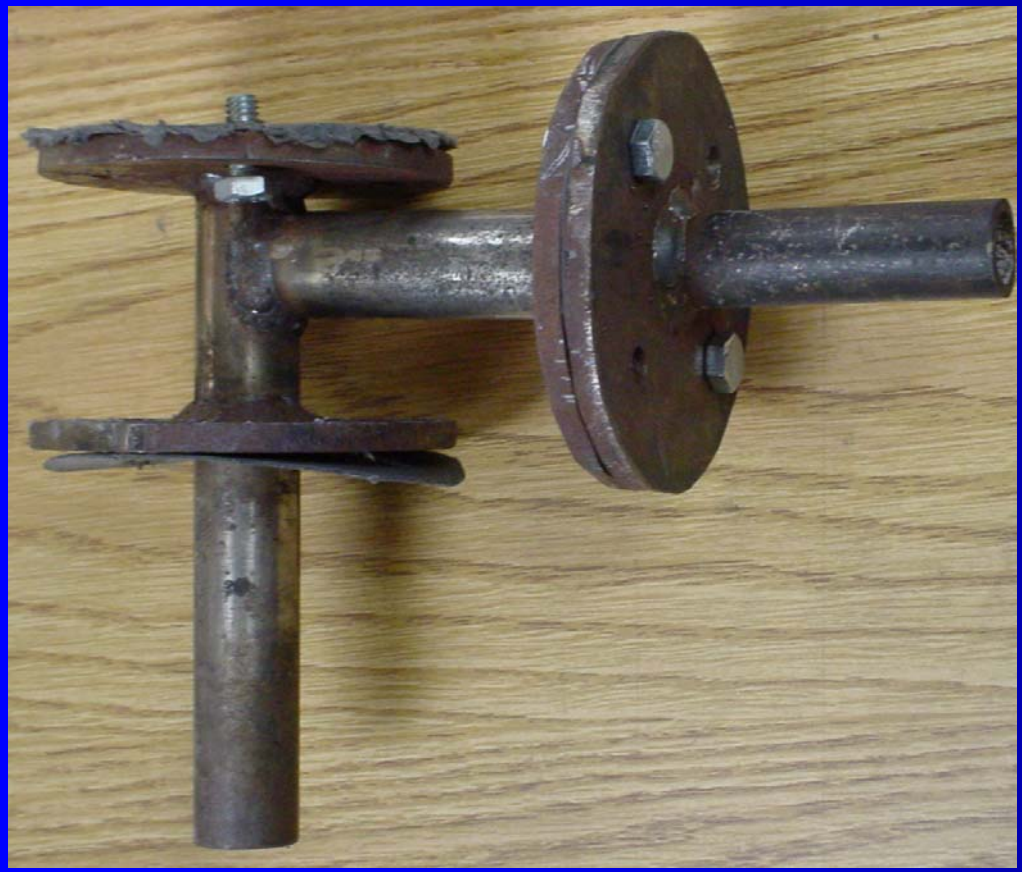
Thermocouple Assembly Design



Thermocouple Assembly Design (cont.)

- A special sleeve was designed to host the thermocouple, which can allow high-pressure nitrogen gas to go through and blow the dirt off the thermocouple tip. The sleeve will be made of a 1-inch stainless steel tube. Two flanges will be welded to the sleeve. The one close to the tip will be used to connect to the gasifier simulator. The other flange will be connected to thermocouple flange, which will be attached to the thermocouple.

Thermocouple Assembly



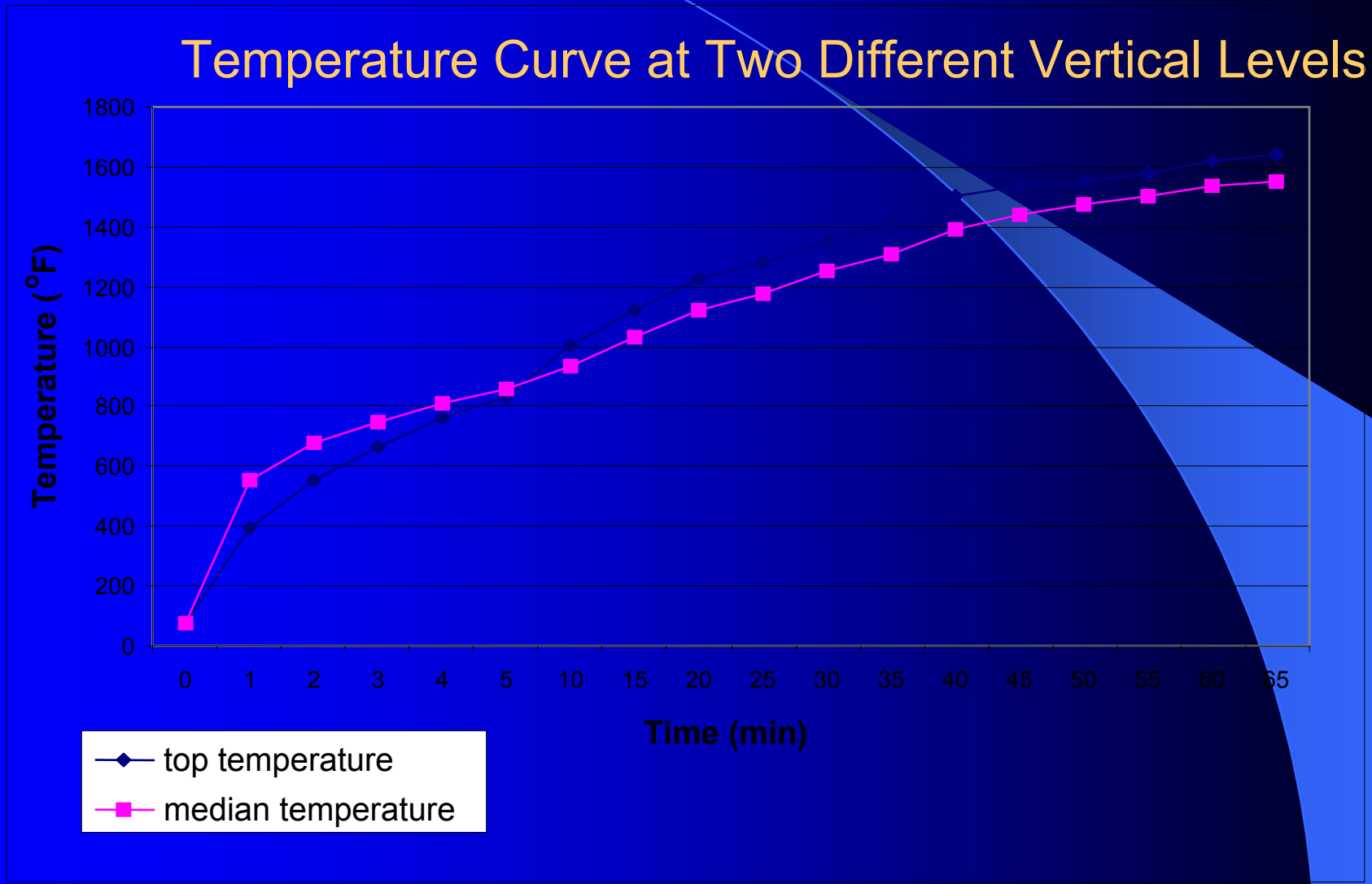
Systematic Tests

- Has proved the similarity between gasifier simulator and real gasifiers
- Has conducted tests under different operation conditions when the thermocouple is clean.
- Has conducted tests under the corresponding operation conditions when the thermocouple is polluted.
- Has conducted tests under the corresponding operation conditions when the polluted thermocouple is equipped with special cleaning methods.

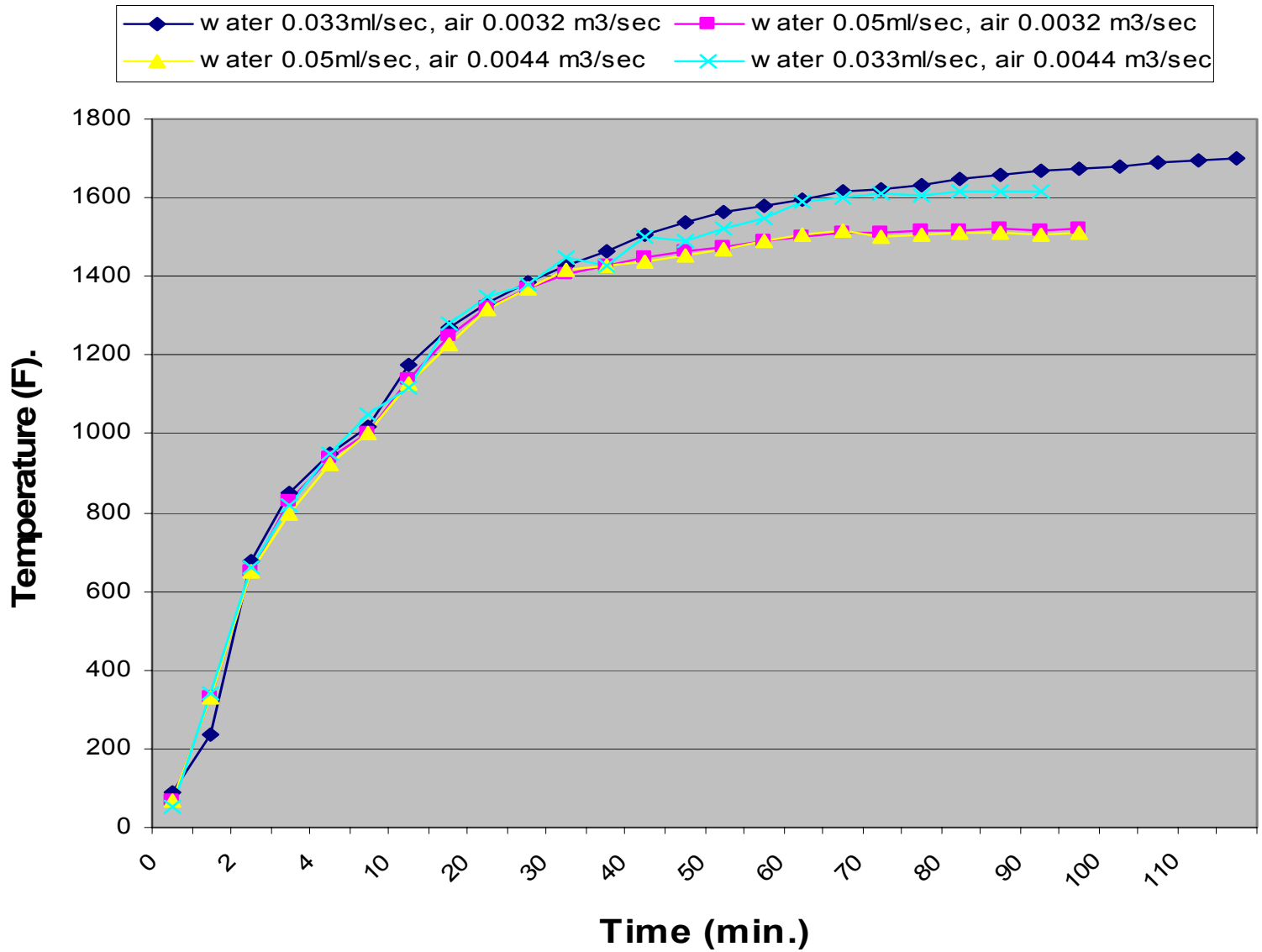
Design of Experiments

Run	Airflow Rate	Water Flow Rate	Dust Amount	Vibration	Amonia
1	-	-	-	+	-
2	+	-	-	-	-
3	-	+	-	-	-
4	+	+	-	+	-
5	-	-	+	-	-
6	+	-	+	+	-
7	-	+	+	+	-
8	+	+	+	-	-
9	-	-	-	-	+
10	+	-	-	+	+
11	-	+	-	+	+
12	+	+	-	-	+
13	-	-	+	+	+
14	+	-	+	-	+
15	-	+	+	-	+
16	+	+	+	+	+

Systematic Test Results



Systematic Test Results (cont.)



Analysis of Variances (ANOVA)

```
Number of obs      =         4      R-squared      =
    0.9983
Root MSE           =       4.5      Adj R-squared  =
    0.9948
Source      Partial SS      df           MS              F
    Prob > F
------------------------------------------------------------------------
------------------------------
Model          11688.5       2       5844.25         288.60   0.0416
water              132.25    1       132.25             6.53
    0.2375
air            11556.25      1       11556.25        570.68   0.0266
Residual           20.25     1       20.25
------------------------------------------------------------------------
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Total          11708.75      3       3902.91667
```

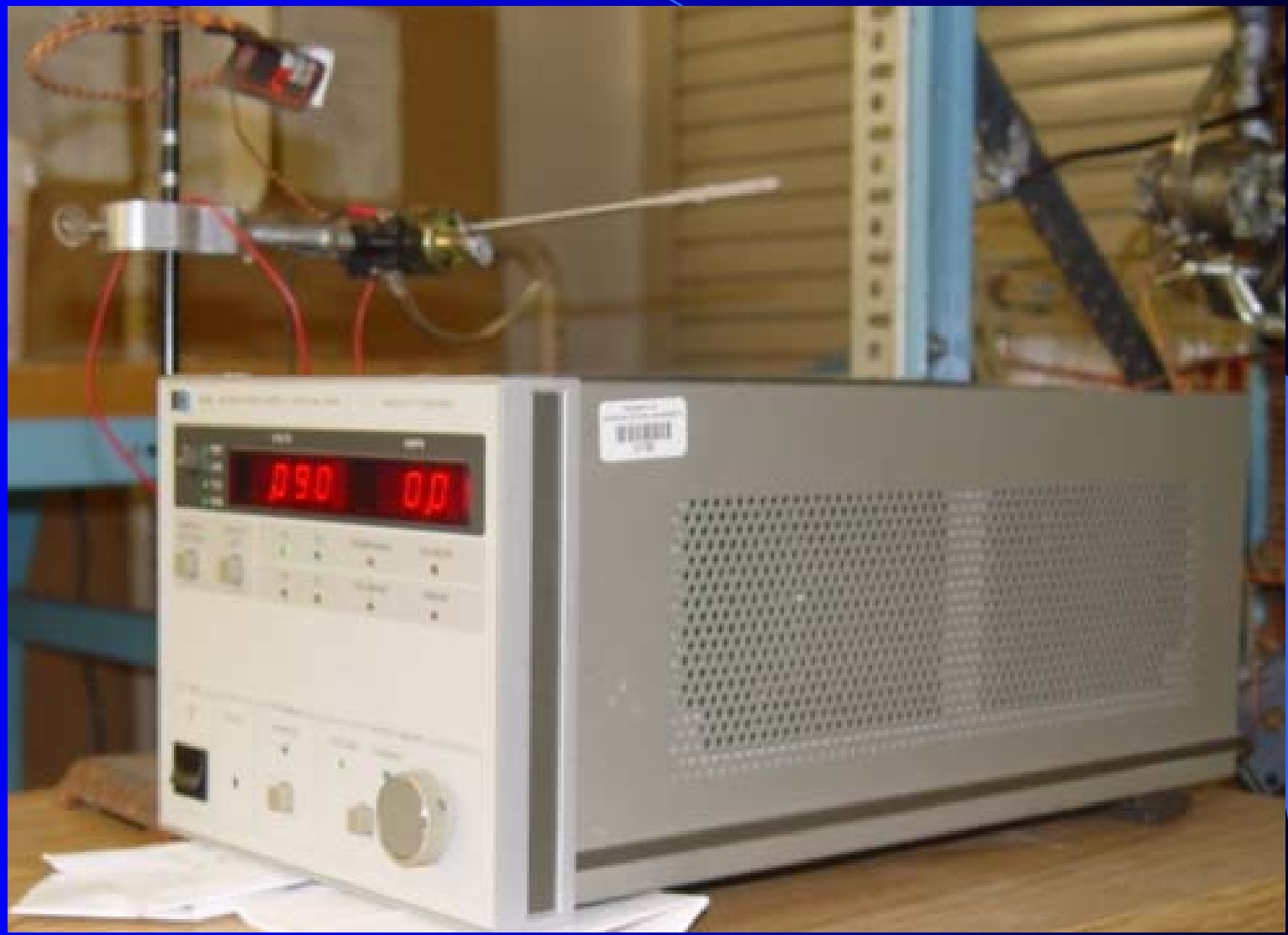
ANOVA (cont.)

- The water feeding rate had a significant impact on the temperature measurements in the gasifier simulator hot model.
- The airflow rate had a significant impact on the temperature measurements in the gasifier simulator hot model.

Vibration (Ultrasonic/Subsonic) Cleaning Method

- To stop the melted ash from condensation process on the thermocouple tip.
- Subsonic and Ultrasonic vibration were considered and tested.
- Subsonic vibration was created by unbalanced high-speed electric motor.
- Ultrasonic vibration was created by ultrasonic welding devices.

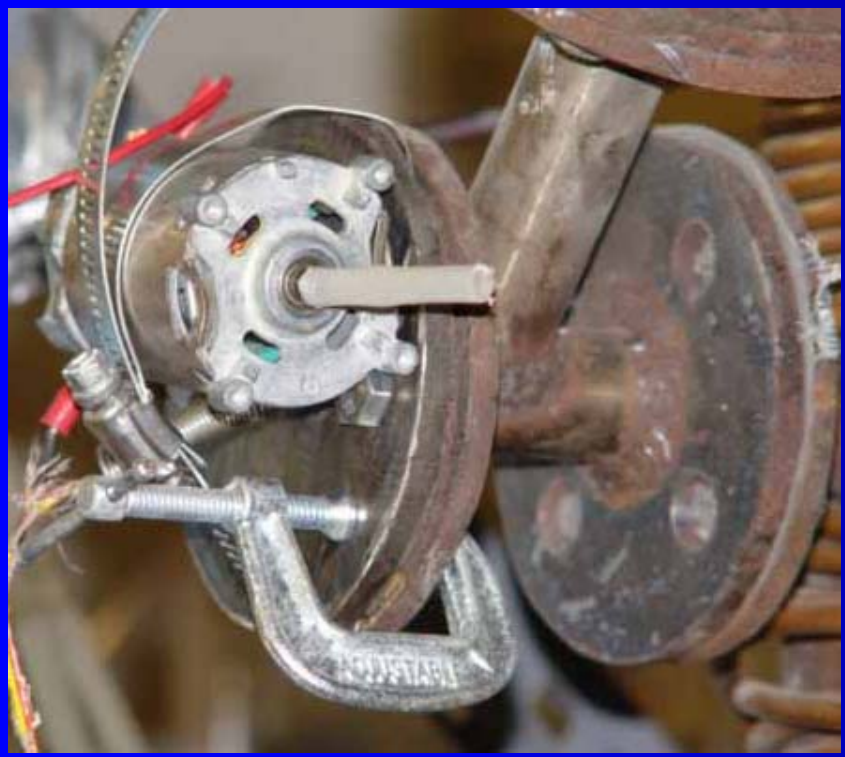
Vibration Test Facility

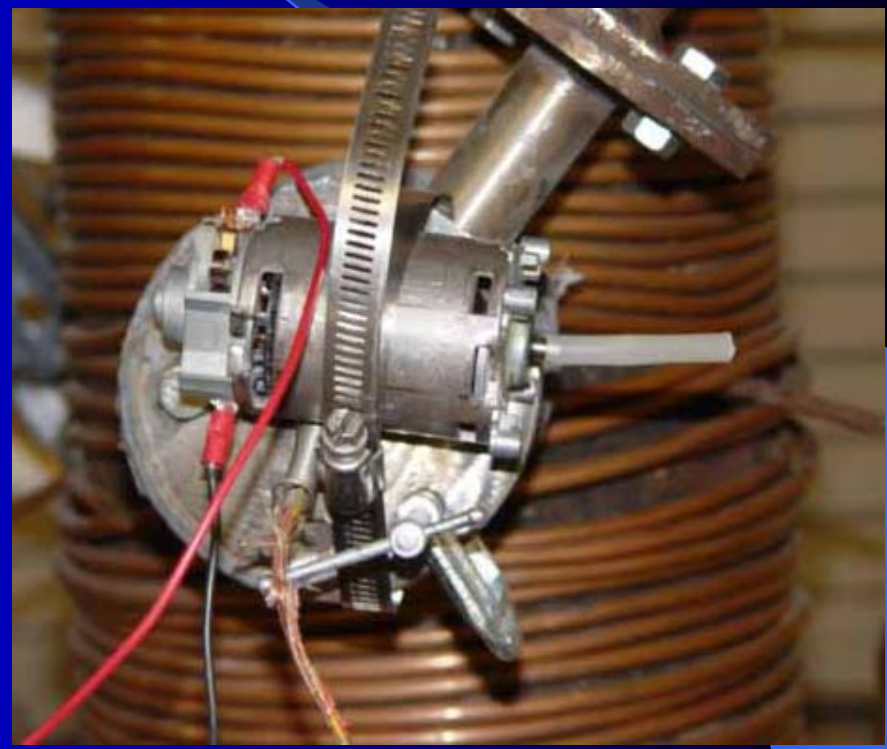


Is Thermocouple Immune to Vibration in Temperature Measurements

- A series of vibration immunity tests were conducted.
- Analysis of Variances showed vibration does not have a significant impact on the temperature measurements in gasifiers.

Vibration Immunity Tests





Ultrasonic Vibration Application to the Thermocouple Cleaning

- The concept of the ultrasonic cleaning tank was first considered.
- The ultrasonic welding device was then considered.
- The electric relay and high frequency shifter were also considered.

Systematic Test Facility

Summary and Conclusions

- 1. The systematic tests in the gasifier simulator are being successfully conducted.
- 2. ANOVA analysis is a very effective method to analyze the complicated experimental system and data.
- 3. Water feed rate did not have a significant impact on the temperature measurements in the gasifier simulator hot model, which proved the stability of the proposed temperature measurement device.
- 4. The airflow rate did have the significant impact on the temperature measurements in the gasifier simulator hot model.

Summary and Conclusions (cont.)

- 5. The specially designed water-feeding device could successfully feed small amount of water into the gasifier simulator.
- 6. The motor can be used to create the thermocouple vibration in sub-sonic frequencies using unbalanced object at the motor shaft.
- 7. The subsonic vibration did not have significant impact to temperature measurements in the gasifier simulator.

Summary and Conclusions (cont.)

- 8. The sub-sonic vibration could reduce the weight of the solid concrete layer on the thermocouple tip.
  9. The sub-sonic vibration frequency and amplitude are believed to have significant impacts to the concrete layer elimination process.

Future Works

- Continue the harmony vibration tests up to ultrasonic frequency ranges.
- Continue the systematic tests in consideration of all five experimental factors.
- Evaluate the impacts of these five factors.
- Develop the control system for the temperature measurement device.

LIST OF PUBLISHED JOURNAL ARTICLES, COMPLETED PRESENTATIONS AND STUDENTS RECEIVING SUPPORT FROM THE GRANT

Symposium Presentation

"Innovative High Temperature Measurement and Analysis in a Gasifier Simulator", Zhu, S., Y. Liu, J. Ngeru, and S.W. Lee, to be presented and published in the Proceedings of 11th Annual Undergraduate and Graduate Science Research Symposium, Morgan State University, April 2004, Baltimore, MD.

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Participated Faculty/Staff and Students

Questions?